Is Science going through a critical stage?

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Abstract

The unexpected discoveries at the beginning of the century, particularly thanks to Heisenberg, Bohr, and Gödel, has driven the science to drastic changes, opening new, extraordinary, and infinite research fields. After this, many scientists saw, and still today see, a crisis, with dreadful meaning, in the science. However, this crisis is only present in that type of science, driven by determinism, which is strictly linked to the common sense.

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The first half of this century has been one of the most intense period in human history: tragic episodes - the two world wars - were interwoven with moments of great cultural activity. At the end of the XIX century, the world was still permeated with an extremely determinist spirit, which was the result of the philosophical ideas of the previous centuries: Enlightment first and Positivism later on. The former - which historically coincides with the XVIII century - tried to "enlighten" the mind of man, seized by ignorance and superstition, through science and knowledge. The latter - borne on the wave of the great scientific discoveries of the time - may well be seen as an

evolution of Enlightment. The word 'positivism' has been introduced by Auguste Comte to make a distinction among the scientific stage of knowledge man had reached and the metaphysical and the theological ones. Positivism recognizes in science the only and real knowledge and takes it as a model for every other part of knowledege. Its scientific rationality and experimental methodology became universal, stonewalling any other kind of reason. This kind of rationality was based upon the convinction that only facts have value, along with their prevision and understading: this was the only way to reach a positive control of phenomena, according to the needs of mankind. Materialism and Scientism came later on and brought to their extremes the positivistic ideas on the superiority of science, of evolutionism and denied the existance of any kind of metaphysics.

However, towards the end of the XIX century, the impossibility in obtaining a satisfactory explanation of some phenomena showed the deep deficiencies of Positivists' deterministic materialism[1]. These problems were overcome thanks to the introduction of a mathematical formalism, the first step towards quantum mechanics. In 1925, the German Werner Heisenberg, Max Born and Pascual Jordan provided a first formulation based on the matrix calculus. One year later, Erwin Schrödinger proposed an alternative way, using waves. Therefore, in 1926, two formalisms were availaible, the wave mechanics and the matrix, capable of investigating on atomic phenomena. The symbolic formulation by Paul A. M. Dirac, an English physicist was then added to these.

The three theories proved to be equivalent; perhaps the most important consequence was to discover that both light and matter have particle–like and wave–like properties. The old debate on the nature of light, dating back to Newton and Huygens, seemed therefore solved, though a new problem arose: that of how could light be both a particle and a wave. Werner Heisenberg and Niels Bohr showed that this inconsistency was only apparent: in 1927, the former published a legendary article, where he enounced the famous principle of indeterminacy [8]. This principle can be summarized with this definition: it is not possible to know simultaneously and with precision the position and the moment of a particle.

On 16th September of the same year, during an intenational congress at Como, held for the centenary of Alessandro Volta's death, Niels Bohr

[1] For a throughout tractation of the history of physics of this period see [14], [1], [5], [12].

introduced the principle of complementarity [2] of which there is no precise enunciation. Bohr spoke about it in this way:

> The very nature of the quantum theory thus forces us to regard the space-time co-ordination and the claim of causality, the union of which characterizes the classical theories, as complementary but exclusive features of the description, symbolizing the idealization of observation and definition respectively [2].

Along with this Bohr brought some examples, such as the debate on the nature of light and of the ultimate parts of matter; after all, what this principle enounces is that matter has a dual behaviour, wave–like and particle–like.

One of the main consequences of these principles regards the concept of reality. On this subject Bohr writes [2] that each observation of atomic phenomena involves a considerable interaction with the measure instrument: therefore neither the phenomenon, nor the instrument can be assigned an indipendent and objective reality, in the ordinary sense of physics. On the other hand, the great Danish physicist adds that an element of arbitrariness is already implicit in the concept of observation, for it depends on who is considered to be the observator and who is the observed.

The fact that classical physics could develop, and the reason why it is not necessary to throw it away today, is due to the extremely small value of the action quantum (we remind that $h = 6.62618 \cdot 10^{-34}$ Js) as to the actions playing in the common sensorial perception. However, these principles should always be borne in mind when speaking about any sector of physics, and even of science, to remember that what one is speaking about is not nature and not even its image.

It is Niels Bohr again who provides us with the correct definition: physics regards what we can *say* about nature, it is the writing of evidences around a praxis (see [11]). Bohr gave this definition of the experiment [3]:

> ... with the word "experiment" we can only mean a procedure regarding which we are able to communicate to others what we have done and what we have learnt.

We have to remember that every time one formulates a theory, one sets hypotheses of effectiveness which generally consist in excluding one factor or another. How many times one has supposed that a phenomenon was linear?

How many times one has supposed it ideal (rigid bodies, geometrical bodies, material points). How many times one supposes that the resistance of an electric device is negligible? How many times is friction considered negligible? And taking into consideration the two-bodies problem, one forgets the interactions among the bodies of the universe, isn't it? Physics and engineering are permeated with hypothesis of this kind, without which we could not adventure in building models or formulating theories. The more or less indirect consequences for engineering are constituted by the introduction of the safety factor, by the concept of reliability of devices; in physics we speak about the experimental errors, the domain of validity of a theory and so on. With all these hypotheses, how could one say *what is the nature*? This is not a mere philosophical speculation, a sophism, a formal problem.

Words have a fundamental importance in all human activities. In 1623, Galileo Galilei wrote in his book *Il Saggiatore* that nature was like a book written in a mathematical language [6]. Quantum physics shows that mathematics is not the language of nature, but an invented language created by man through which it is possible to say something about nature. It is a refinement (or an impoverishment?) of language eligible to represent those relations for which the commmon word would result imprecise or far too complex. The importance of mathematics as a language for physics has come up with the advent of quantum physics indeed. As a matter of facts, contemporary physics can be briefly divided in two parts: one based on the analysis of the phenomena for which we have direct experience, of the everyday world and that express itself with the common language. The other is consituted by those phenomena which regard the extremely small (quantum physics) and the speeds near to that of light (relativistic physics), of which we have neither direct experience nor an adequate language to describe them, except that of mathematics. When speaking about quantum and relativistic physics an uncorrect use of words could lead to misunderstandings creating inappropriate images. Heisenberg's comment is that we have then to resign to the fact that the experimental observations in the extremely small and in the extremely wide cannot give more than an intuitive image; whithin these fields we have to learn to do without intuition [9].

However, one is not allowed to think that mathematics is the last hope for Determinism. As a matter of fact the analogous of the principles of indeterminacy for mathematics was expressed by Kurt Gödel in 1931 [7]. In his article, he stated the impossibility to realize the hilbertian program: in 1900, during the *Second International Congress of Mathematicians* in Paris, David

Hilbert introduced a list of 23 problems which covered the most different fields of mathematics [10]. Among these, point 2, relative to the demonstration of non-contradiction of arithmetics, deserves a particular attention. From Hilbert's viewpoint all mathematical theories should have been reduced to formal systems: then this would have been enough to demonstrate the non-contradiction. In 1930, Gödel wrote an article, which was published one year later where he demonstrated that this was not possible. As a matter of facts, within a sytem like that expressed by Bertrand Russell and Alfred N. Whitehead in the *Principia Mathematica* it is possible to express propositions which are not decidable within the system's axioms. One can view this as the impossibility of defining each concept through a unique and defined linguistic universe.

The expression of these formulations made many scientists feel dejected, they cried science had reached its end. Many of them did not want to leave the anchor of an objective reality, existing independently from everything else: Einstein, Planck, Schrödinger so to cite some of them. Einstein's positions has nearly become legendary: during the Solvay congress, held in 1927 in Bruxelles, he expressed many ideal experiments which should have invalidated the principles of quantum mechanics, though they were punctually disproved by Bohr and Heisenberg. Einstein recognized the validity of quantum mechanics though he refused to accept it, summarizing this aprioristic refusal with the famous sentence "God does not play dice" to which Bohr replied that "Our problem does not not consist in telling God how he has to govern the world" (see [9], Chapter 7).

Nowadays, many physicists still refuse quantum physics for they consider it irrational or mystical. Even today they are calling it crisis: Marcello Cini speaks about a "paradise lost" [4] and not long ago Eugenio Sarti wrote an article for this Review [13].

Using the term 'crisis' they suggest something dreadful, that will lead to the very end of science. Some scientists think that this crisis is already operating and it is the result of the principles up to now discussed, others think it will come along with the Great Unified Theory. Nevertheless, the word 'crisis' shows no dreadful meanings: it derives from the Greek $\kappa\rho\iota\sigma\iota\varsigma$, which in turn is linked to $\kappa\rho\iota\nu\omega$, which means 'to divide' and metaphorically 'to decide' [2]. It were the Greeks the first to introduce the process of analysis

[2]It is interesting to see that the word 'science' as well comes from the sanscrit root *skad-*, *skid-*, which means 'to cut', 'to mince'; knowledge should then result from the separation

as a *division* of a thesis in propositions, leading more easily to truth. If, within a theory, we separate or, better, underline, some essential laws we could then consider them as principles for a new theory. Analysis is essential to science because, as Paolo Zellini writes [15], this *divide et impera* preserves the thesis from the risk of a total rejection deriving from an excess of rigidity or from an unconscious desire for barreness; it diverts the attention on the central parts of the demonstration, revealing those hidden hypotesis faked by counterexamples. Counterexamples do not actually fake the thesis as a whole, rather some of its implicit assumptions, not always recognized when trying to demonstrate it. A scientific theory thrives until these implicit assumptions, eligible to be faked by counterexamples, exist. The surprising thing is that, as Imre Lakatos writes (see [15]), these concepts grow by themselves and generate a maze of problems.

The word, let it be mathematical or from the common language, cannot be managed: all those huge programs that claim to ground some discipline, that believe to find the ultimate formula, the pill, the magic potion which gives knowldge, well all these programs cannot but result in some grounds crisis: as Lakatos wrote (see [15]), both certainty and banality are infantile illnesses of knowledge.

However, this ground crisis should not degeneratre in a skeptical cynism or in mysticism. The principles up to now discussed suggest the solution for they do not imply the end of science, not at all. That is the good of it, because thanks to these principles an unknown, endless universe is opened wide to us, waiting to be analyzed.

The infinite that we still consider with mistrust, in ancient Greece was $\alpha\pi\epsilon\iota\rho o\nu$, 'without limits', 'unlimited'. Aristotle (see [16]) wrote that infinite is not that out of which there is nothing, though that out of which there is always something. The unlimited cannot therefore be regaded as a complete whole: what is completed has an end and the end is a limiting element, while $\alpha\pi\epsilon\iota\rho o\nu$ shows for its very meaning the absence of any limits (see [16]). Tannery (see [16]) suggested to derive Anassimander's $\alpha\pi\epsilon\iota\rho o\nu$ from $\pi\epsilon\iota\rho\alpha$ meaning 'knowledge', instead of deriving it from $\pi\epsilon\rho\alpha\varsigma$, 'limit': in this way the unlimited became the unknowable (see [16]).

Anyway, the importance on the infinite is in its becoming. As Aristotle wrote in his *Physics*, if the limit is what make each object exist, giving it a form, the infinite is its opposite principle that prevents each object to be

of notions.

fixed in its limits, within its boundaries. Anassimander thought that the $\alpha\pi\epsilon\iota\rho o\nu$ was the very principle of becoming.

When somebody will find the ultimate formula, then the end of mathematics and physics will come. Bohr's, Gödel's and Heisenberg's essays do not state the limits of science, on the contrary they show the non-existance of these boundaries.

These are no comfortable ways, as some of the stronger supporter of Determinism thought, rather these are big steps forward made by science. It is not by chance that this revolution has taken place in mathematics, a highly sophisticated language, and in physics, that uses this language intensively.

If we really look for a crisis in science we will see that there is one in mathematics and in physics for these sciences look for completeness, for the seek their beginning to determine their end though this was already clear in 1927 for physics and in 1931 for mathematics. Nevertheless there is who prefers to ignore these questions and go on trying to build a deterministic world, complete, limited, foreseable. We are not stating that this is wrong or that this should not be done, for when one researches it is not possible to say what is to be done or not. The important is to do and then who knows if from these researches some interesting hint may come.

However, it is essential for research to investigate the infinite.

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